TRACK SPARK CHAMBER FOR OBSERVATION OF HIGH ENERGY NUCLEAR INTERACTIONS.

G.E.Chikovani, V.A.Mikhailov, V.N.Roinishvili.

Institute of Physics of the
Academy of Sciences of the
Georgian SSR

Rapid growth of the number of experiments in the field of physics of high energy particles made necessary creation of new types of detectors for charged particles. A spark chamber is one of such detectors; different types of this chamber have found wide application in physical experiments. But the principle of their operation was the same as in the first works made by S.Fukui and S.Miyamoto /I/.

We have offered another in principle method for registration of particles in a spark chamber based on the so-called "track" regime of its work /2,3/. At this regime the chamber works as a real track device reproducing tracks quite similar to those in a cloud chamber.

The present paper is devoted to the results of the study of properties of a track spark chamber.

In a track spark chamber the development of streamers is artificially broken at an early stage and the track of a particle is obtained as luminous columns situated on the trajectory of the particle. The length of the column in the direction of the electric field is about several millimetres and their average width is about two millimetres.

The track chamber , unlike ordinary spark chambers, gives an exact space reproduction of tracks of particles moving at arbitrary angles with respect to the electric field.

The experimental device used to study properties of the track chamber is shown schematically in Fig.I . Chamber /4/ is a rectangular glass box, its size is 100cm x 60cm x 20cm (the last number is the depth of the chamber) glued with exopide gum. The chamber is filled with neon of "especial purity" at the pressure of 1 atmosphere. Stereophotography of tracks is performed through electrode grid /3/. The high voltage pulse from a Marx pulse generator with the equivalent capacity of 200pF is applied to this electrode. The duration of the pulse is regulated by the change of the distance of shunting spark gap /5/. The operation of the chamber is controlled by the coincidence of Geiger-Müller counters /1/, /2/. An electronic circuit allows to change the delay time τ_d between the passage of a particle and the triggering of the high voltage pulse generator within the range $1 \div 200 \mu$sec. A separate camera is used to take photos of tracks through a side wall.

Examination of the photos obtained through the side wall of the chamber /Fig.2/ shows that at long durations of the feeding pulse $\geqslant 10^{-7}$ sec the discharges spread from one electrode to the other /Fig.2a/ and have a cluster form with a nod situated in the point of the position of a primary electron. Some decrease of the pulse duration leads to the detachment of discharges from the chamber wall and to their localization in the volume of the gas /Fig.2b/. If to decrease further the duration of the pulse to about $5 \cdot 10^{-8}$ sec one can obtain the length of streamers about some millimetres. Then their brightness sharply decreases and taking their photos from the side wall becomes rather difficult . But the brightness of streamers along the direction of the electric field is sufficient to obtain photos of high quality. Further significant decrease of the duration of the pulse leads to disappearance of the luminous centres. Duration of the pulse at the "track" regime can be changed in a very narrow interval which is equal to some nano seconds. This interval is by the order of magnitude equal about 10% of the time necessary for the development of an electronic avalanche and its transformation into streamers. When the amplitude of the high voltage pulse is decreased, the time of the action of the pulse should be made longer and vice versa , it should be shortened at the increase of the amplitude.

All these facts imply very strict requirements on the formation of duration of a high voltage pulse. In the case of formation of duration of a pulse by means of RC-chain, it is difficult to achieve the same good registration of both large groups of particles and of a single particle. If to tune the chamber for the "track" regime for a single particle then at the passage of a large group of particles the tracks of a shower will be indistinct because of a slight decrease of the high voltage pulse at parasitic inductances. And in the case of tuning of the chamber for the "track" regime for a group of particles, streamers will be overdeveloped for single particles. The method of formation of duration of the high voltage pulse by means of a shunting gap has no these disadvantages. In the case of the passage of a group the decrease of voltage is automatically compensated by the increase of the length of high voltage pulse which occurs because of the increased delay time of the breakdown of the shunting gap. While operating with the shunting gap we obtain in the chamber tracks of high quality both for single particles /Fig.3/ and for the group /Fig.4/.

The examination of stereophotos shows that the coordinates of luminous centres along the direction of the electric field can be determined to an accuracy of two millimetres.

Different characteristics of the spark chamber at the "track" regime were studied. They include: the number of luminous columns, the width of the columns and root mean-square deviation of the columns from the real trajectory depending on the delay time between the passage of the particle and the moment of supply of the high voltage pulse.

At the "track" regime tracks of high quality in the spark chamber were obtained in all the interval of delays studied by us : $I \div 200 \mu$sec /Fig.3 and Fig.5/. At the increase of delay the width of the high voltage pulse should be increased a little if one wishes to obtain tracks of high quality. So, for instance, at the increase of the delay time till 200μsec the length of the pulse should be increased for 5-7% in comparison with small delays of the order of $I \mu$sec.

The width of the columns at small delays fluctuates very slightly and at the delay $\tau_d = I \mu$sec the mean value of the diameter of the columns is I.6mm. The fluctuation of the diameter of the column slightly increases with the increasing delay.

The number of luminous columns increases very slowly with the increase of the delay. At the delays smaller than $II \mu$sec the number of the luminous columns N per Icm of the track is equal approximately to I.4 and at the delay of 200μsec to 2.8 .The number of luminous columns at the "track" regime is about an order smaller than the number of the primary electrons.

At very big delays $\tau_d \geq 200 \mu$sec root mean-square deviation of luminous centres - from the trajectory of the particle coincides with the diffusion deviation of primary electrons. The dependence of the root mean-square deviations of the luminous columns from the real trajectory on the delay time in the range $I \div II \mu$sec is given in Fig.6 . The experimental points are plotted as triangles. The mentioned errors correspond to two standard deviations. The solid curve corresponds to the diffusion of primary electrons in neon at the value of the diffusion coefficient $\mathcal{D} = 2 \times I0^3$ cm^2/sec.

As one can see in Fig.6 the experimental points lie much lower than the diffusion curve and the discrepancy cannot be explained by the errors of measurement. The discrepancies are caused by the nature of the spark chamber operation at the "track" regime. They indicate that at small values of delay time and at the duration of the high voltage pulse necessary to obtain the "track" regime electron clusters have the main part in the creation of luminous centres and not single electrons. Avalanches created by such clusters firstly reach the critical size necessary for the transformation: an avalanche - streamer earlier and secondly they fluctuate less than avalanches created by single electrons. The results of the calculation of avalanche fluctuations created by different number of primary electrons are given in Fig.7. The distance passed by an avalanche in the electric field is put along the abscissa axis in the units of $\ell_{max}=\frac{20}{\alpha}$ (where α is the first coefficient of Taunsend) and the probability of an avalanche transformation into a streamer after passing the distance in the electric field is put along the ordinate axis. It is natural to assume that two electrons at the distance less than the size of the luminous column d , in our case I.6mm, form an electron cluster and create one avalanche. On the other hand, while developing in the electric field, one of the avalanches, because of fluctuations will be progressing quicker and will be transformed into a stteamer , and then it will supress the development of the near by avalanches by its volume charge field. Therefore there should be some distance z_0 nearer which two avalanches will not develop into a streamer at the same time /4/. It is possible to estimate that for the case of the "track" regime from the observed number of the luminous columns at small delays (τ_d= Iμsec) z_0 = 6.7mm.

To calculate the visible width of the track depending on the delay is very difficult in the general case. But it can be estimated easily in the two extreme cases, when the diffusion width is so big

when the diffusion wide is less then d, and that the mean distance between the adjacent electrons is much bigger than d . In the first case the fluctuation of the centre of the electron cluster from the real trajectory will be

$$\sigma = \frac{\sigma_0}{\sqrt{m}}$$

where m is the mean number of electrons of the cluster. The calculated value for the delay $\tau_d = 1\,\mu sec$ is shown in Fig.6 by a circle.

In the case of big delays the columns develop from single primary electrons and therefore the observed width should coincide with the diffusion one.

In Fig.8 there are shown the results of the appearance of streamers with the time. The calculations were made with taking into account the fluctuation of the development of avalanches, cancellation of avalanches one by another and clustering of closely spaced electrons into one avalanche. Along the abscissa axis the distance is put passed by avalanches in the electric field and the number of the visible centres in relative units is put along the ordinate axis.

As it is seen in Fig.8 avalanches begin to transform into streamers after [illegible] the field the way $\ell = 0.89\,\ell_{meek}$. During the time when aval[illegible] pass the way from $0.89\,\ell_{meek}$ to $0.93\,\ell_{meek}$, 90% of all the centres which could have developed, already reveal themselves. Thus the whole transformation an avalanche - luminous centres takes about 10% of the total time of the track formation. The further increase of the pulse will lead to the change of the track to the worse. When the delay is increased, as it follows from Fig.8 , the revealation of centres should begin later. Therefore the required duration of the high voltage pulse should be correspondingly longer. At the delays $\tau_d = 200\,\mu sec$, as it follows from Fig.8 , widths of the pulse should be for 5% bigger than at small delays and it is well confirmed by experimental observations. Besides, as it is seen from the figure, the process of the transformation an avalanche-streamer at small delay times /Iμsec / takes less time than at big delays / 200μsec /. Therefore to the end of the pulse, at small delays, in agreement with the experiment, the sizes of the luminous centres should have less spread than at big delay time. The number of luminous colúmns calculated according to this model agrees well with the observed ones.

In conclusion it should be noted that in the "track" chamber one can obtain tracks about I metre long and even longer, at the same time luminous columns are very closely spaced with the trajectory of the particle. All these facts have fundamental importance for measurement of a charged particle pulse in a magnetic field. For instance, the maximum measurable pulse of charged particles for our chamber should be equal to 300 BeV/c (at the delay time τ_d = Iμsec, at the length of the tracks equal to I00cm and the strength of the magnetic field equal to $7.I0^3$ oersted).

It seems that the track spark chamber is a very perspective device for studying various problems of high energy particles because of its exact reproduction of tracks of particles in the space and registration both single particles and large groups of particles as well as the tracks of the particles generated in the chamber itself.

R E F E R E N C E S.

I. S.Fukui and S.Miyamoto, Nuovo Cimento II,II3, I959.

2. V.A.Mikhailov, V.N.Roinishvili, G.E.Chikovani JETF 45, 8I8, I963.

3. G.E.Chikovani, V.A.Mikhailov, V.N.Roinishvili, Physics Letters 6, 254, I963.

4. S.Fukui and S.Miyamoto, Journal of the Physical Society of Japan, I2, 2574, I96I.

Figures to the paper of G.E.Chikovani, V.A.Mikhailov, V.N.Roinishvili "Track Spark Chamber for Observation of High Energy Nuclear Interactions ".

Fig.I The scheme of the device:

I-2 - Geiger-Müller counters.

3 - Grid electrodes.

4. - Glass box filled with neon (size I00cm x 60cm x 20cm).

5 - Shunting spark gap.

Fig.2 Photos of charged particle tracks in the spark chamber, taken through the side wall.

2a - Photo of a track at the duration of the pulse $> 10^{-7}$ sec.

2b - Photo of a track at the duration of the pulse $\gtrsim 5 \cdot 10^{-8}$, not short enough to obtain the track regime.

Fig.3 Stereophoto of a single particle track at the operation of the chamber at the track regime.

Fig.4 Stereophoto of a shower of particles at the operation of the chamber at the track regime.

Fig.5 Photo of a track at the delay time between the passage of the particle and the supply of the high voltage pulse $\tau_d = 200\,\mu$ sec.

Fig.6 Root mean-square deviations of luminous columns from the trajectory of a particle as a function of τ_d . Triangles are experimental values. (Errors plotted in the figure are equal to two standard deviations γ. The circle is the calculated value of the root mean-square deviation for an electron cluster with the "multiple" equal to 3.9 .

Fig.7 Probabilities of the transformation of an avalanche into a streamer depending on the length of the way passed by an avalanche in the electric field at different initial number of electrons - n

Fig.8 Dependence of the number of luminous columns (in relative units) on the length of the way passed by avalanches ℓ, in the electric field, for different values of τ_d. Curve I is for τ_d = I μsec, and N_{max} = I.44 . Curve 2 is for τ_d = IO μ sec, and N_{max} = I.5 . Curve 3 is for τ_d = 200 μ sec and N_{max} = 4.48 .

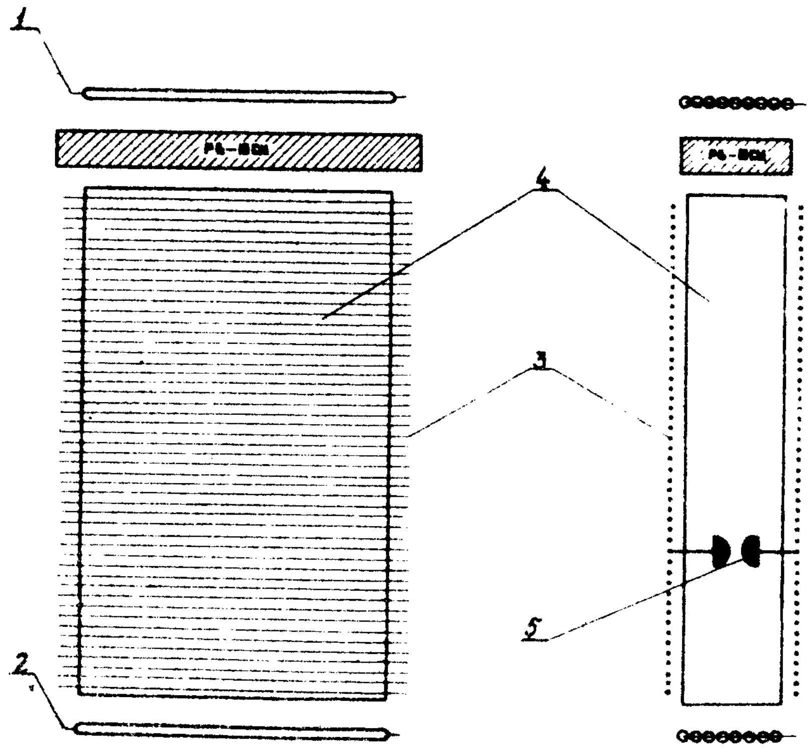


Fig. 1

Fig. 2a

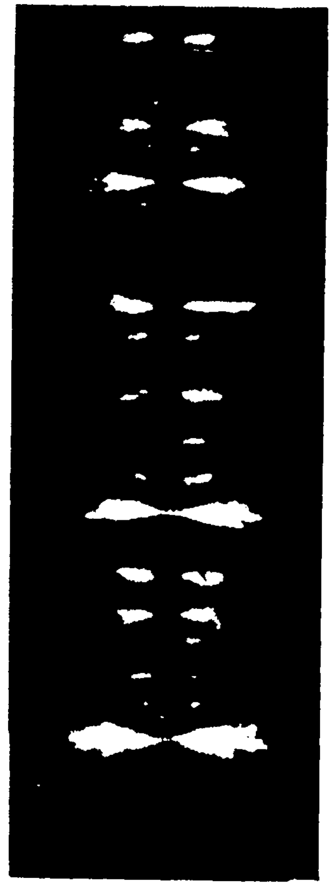


Fig. 2b

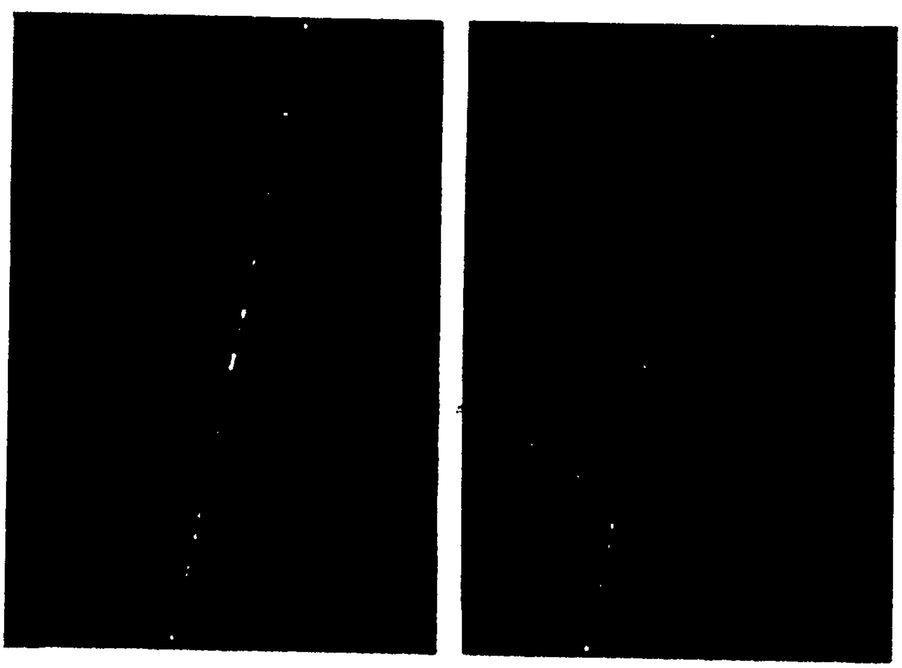


Fig. 3

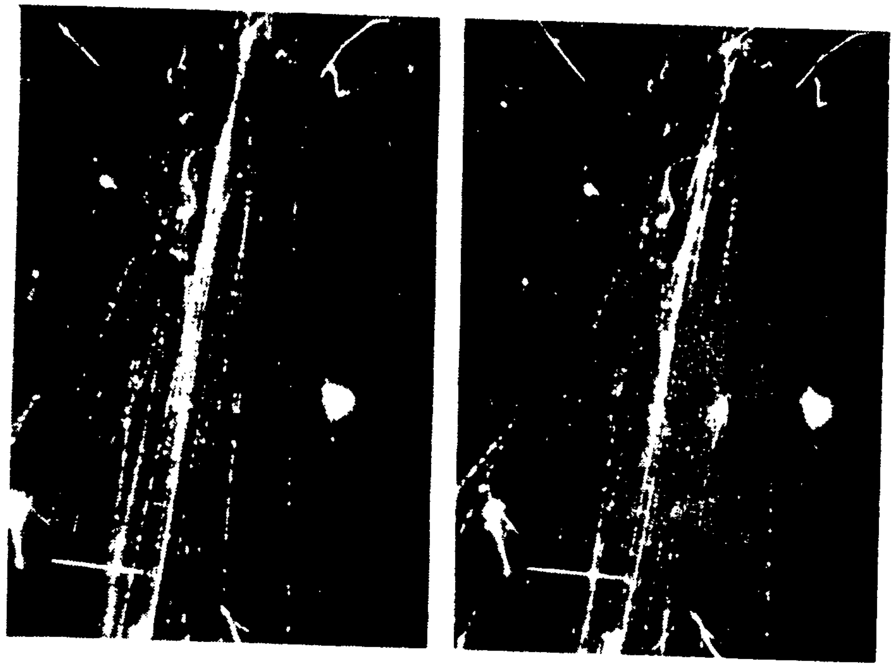
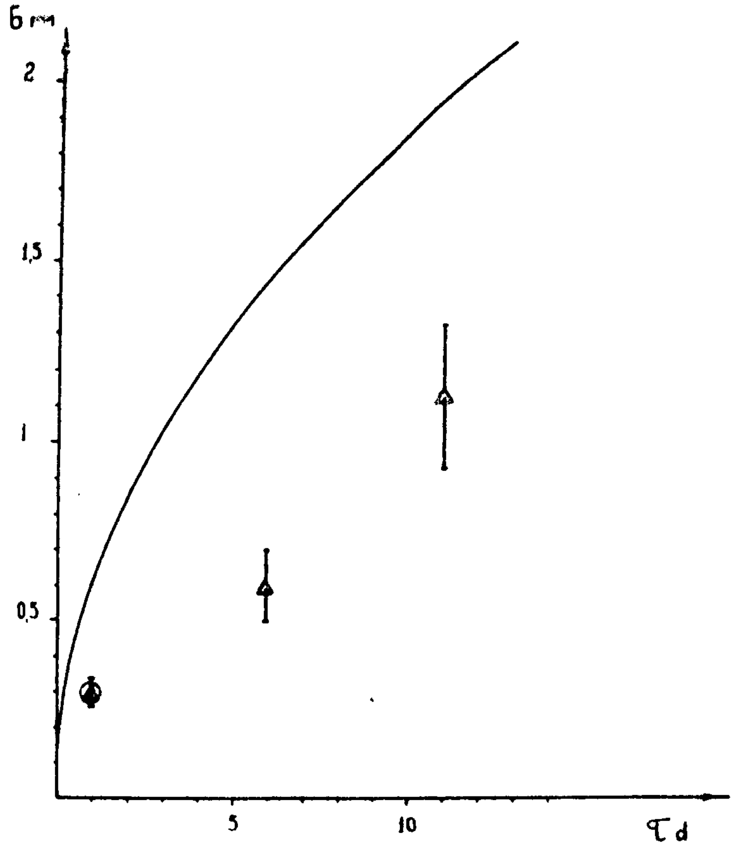


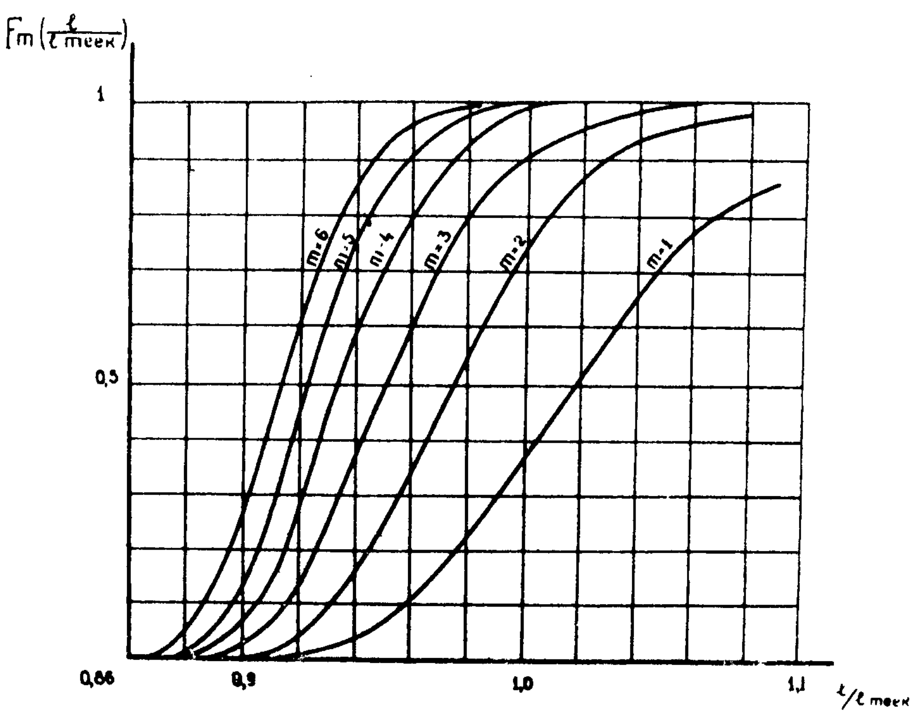
Fig. 4

Fig. 5



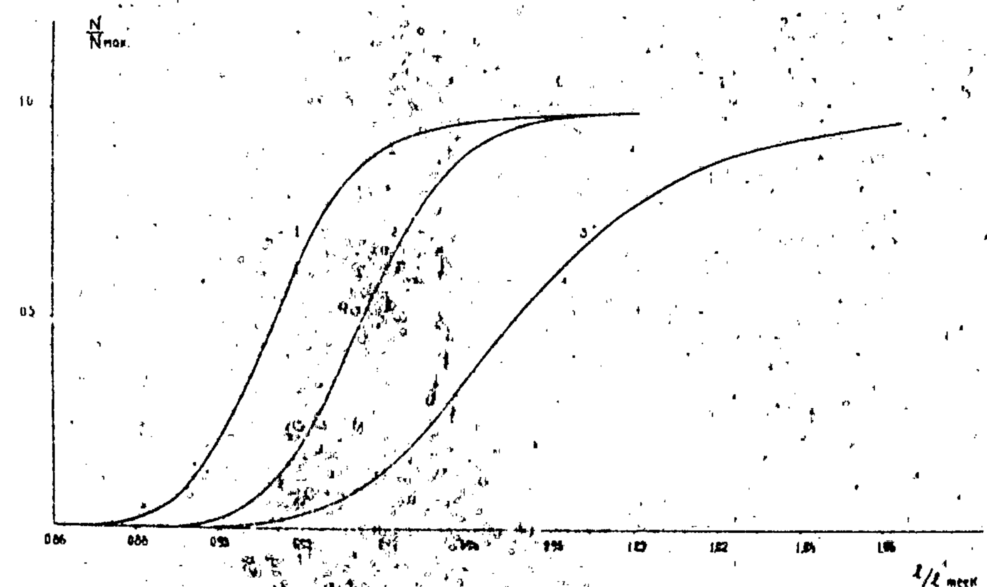
σm
2
1,5
1
0,5
5
10
τd

Fig.6



Fm(t/t meek)
1
0,5
0,86
0,9
1,0
1,1
t/t meek
m=6
m=5
m=4
m=3
m=2
m=1

Fig.7



STAT

Page Denied

Declassified in Part - Sanitized Copy Approved for Release 2014/05/21 : CIA-RDP80T00246A025900230001-9